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The Effect of STEAM on Science Learning on Student Learning Achievement: A Meta-Analysis

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Abstract: STEAM is a popular approach used in learning by integrating several fields of science in the form of science, technology, engineering, art, and mathematics. This study aims to determine the effect of size from studies that discuss the effect of STEAM on science learning on learning achievement. The moderator variable consists of the level of education and the distribution of regions. This research is a meta-analysis study by collecting quantitative data to calculate the effect size of each study. Studies were collected through national and international journal research using Google Scholar and ERIC in the range of 2012 to 2022. The effect of STEAM on science learning on student learning achievement had an average size effect score of 0.71 in the moderate category obtained from 20 studies. The distribution of studies discussing STEAM is most commonly found in the South Korean region. The influence of STEAM varies on the level of education dominated in elementary schools.

Keywords: Learning achievement; Science; STEAM

Introduction

Significant technological advances in the 21st century are driving changes in various sectors of life. Knowledge is needed in the advancement of digital technology to be able to be globally competent. Technology has provided novelty in the learning process by presenting a variety of problems in the learning process from various fields of science (Ichsan et al., 2023; S.-H. Kim, 2017; Vaidya et al., 2018). Therefore, technological advances encourage everyone to have diverse and complex knowledge (Y. Lee et al., 2018). Advances in technology make it easier to connect one field of science with another and provide motivation for students to learn (Festiyed et al., 2022; Taljaard, 2016). The integration of several fields of science will produce complete knowledge for each student.

In solving a problem, it must be studied in various corners of the field of science. Problems in science are related to natural phenomena. Problems arising from a natural phenomenon can be studied in various aspects of the field of science, such as the beauty caused, the technology involved, the tools needed to solve problems, and mathematical calculations in obtaining quantitative data (Asrizal et al., 2018). Each field of science has an important role with other fields of science. In the learning process, the integration of various fields of science is needed to produce complete knowledge for students (Dhanil & Mufit, 2021; Mufit et al., 2022). The impact gained on students by involving various fields of science in discussing a problem will result in diverse angles and broad solutions to solving the problem (Nicholls et al., 2018). So that in the learning process, integration between science, technology, engineering, art, and mathematics is needed. Learning that applies five such subdisciplinary approaches is referred to as the STEAM approach.

STEAM is a learning that integrates science, technology, engineering, art, and mathematics, which contain each other between each field of science (Azhar et al., 2022; Khine & Areepattamannil, 2019). As a learning approach, STEAM provides updates in creating ideas for solving problems based on five integrated disciplines (Madden et al., 2013). The integration of several fields of science in a learning process provides a broad understanding to students in solving a problem from various points of view (Drake & Reid, 2018). Thus, the STEAM approach is widely used to train students'

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ability to think critically and creatively (Suganda et al., 2021).

The STEAM approach has been widely used in producing a complete learning process involving various fields of science, so many researchers have conducted studies on STEAM. Various forms of research have reported the effects of STEAM on learning with mixed results. The researchers found improved student learning outcomes when applying STEAM in science learning (Jeong et al., 2021). The STEAM approach is able to encourage improved student problem-solving through the integration of knowledge in multidisciplinary (Ozkan et al., 2021). The use of STEAM motivates students to learn through a variety of knowledge from different points of view (Wandari, Wijaya, & Agustin, 2018). In contrast, the use of STEAM has no influence on student learning outcomes (S. Min et al., 2021; Tae, 2016). STEAM learning is difficult to consider difficult to apply in schools because it involves many clusters of knowledge and supporting facilities (K.-W. Jeong et al., 2021). In addition, not all students have the same interest in learning through the STEAM approach, which has an impact on low student learning outcomes (S.-A. Min et al., 2021). Based on these problems, it is necessary to identify the influence of steam in learning through meta-analysis. Meta-analyses were conducted to produce more accurate conclusions and broader generalizations regarding the impact of STEAM on learning outcomes

Previous studies have discussed STEAM through bibliometrics and literature reviews. Literature review related to the grouping of the use of STEAM approaches in learning spread across every region in the world (Pahmi et al., 2022). Another literature review was conducted on the STEAM approach to computer learning and science (Psycharis, 2018). In addition, bibliometrics related to the use of the STEAM approach in learning (Marín-Marín et al., 2021). The difference in previous research related to STEAM is the focus of discussion in the form of meta-analysis on student learning outcomes. In addition, moderator analysis involving learning achievement, level of education, and regional distribution (Akçayır et al., 2017; J Garzón et al., 2019; Juan Garzón et al., 2019). The variable is identified as a moderator variable.

The diversity of the results of previous research data on the influence of STEAM learning on students' science learning achievements, so it is necessary to map the results of the study. Researchers are interested in conducting meta-analysis research to determine the effect of STEAM learning on student learning achievement. To achieve this goal, characteristics are identified based on learning achievement, level of education, and regional distribution. In order for the research carried out to be directed, three questions (RQ) are asked as follows:

RQ1: How does STEAM affect student learning achievement?
RQ2: How does STEAM's influence vary by education level?
RQ3: Which country has found the most studies discussing STEAM in science learning on student learning achievement?

Method

This study is a meta-analyst study that presents strong data in the form of size effects from each study. The studies used in the meta-analysis are sourced from national and international journals. Searches are conducted through Google Scholar and ERIC using STEAM keywords combined with education, achievement, and science. Search restrictions on titles and excluding sections in articles that use those keywords. The studies used in the meta-analysis ranged from 2012 to 2022, the study measured the impact of STEAM on student achievement, the study provided sufficient data information to calculate ES (sample size, mean, standard deviation, and t value), STEAM was applied to science learning and STEAM search was not included in early childhood education.

In finding the studies used, a systematic review and meta-analysis (PRISMA) were carried out to obtain systematic results. The flow chart of the systematic review follows the PRISMA rules as shown in Figure 1.

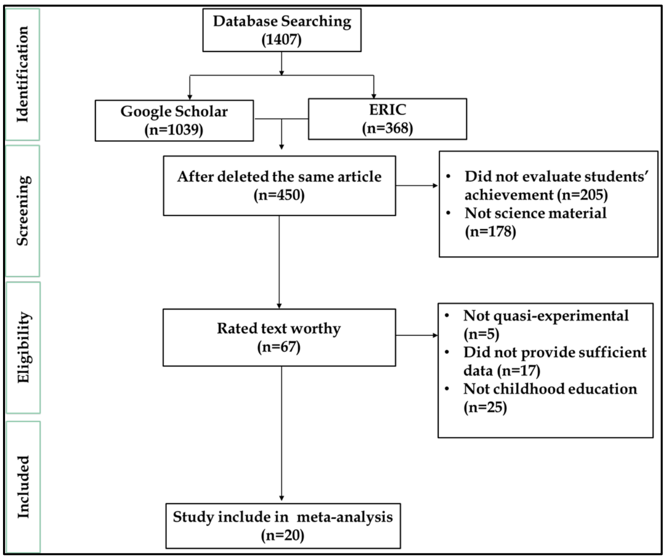

Figure 1. Meta-analysis flow

The purpose of the meta-analysis was to synthesize quantitative data from several studies to estimate the effect of STEAM on student learning achievement, in calculating the size effect using the help of Excel and JASP applications. The Excel application is used to process data until it finds a size effect. Furthermore, the JASP application is used in meta-analysis research to look at heterogeneity, forest plots, funnel plots, and publication bias. The equations used to process data in the form of the number of samples, mean, and standard deviation in finding the size effect are calculated using the following.

$$d = \left(\frac{\bar{X}_E - \bar{X}_C}{SD_{Whithin}}\right)\left(1 - \frac{3}{4df - 1}\right) \quad (1)$$

$$SD_{Whithin} = \sqrt{\frac{(n_E - 1)S_E^2 + (n_C - 1)S_C^2}{n_E + n_C - 2}} \quad (2)$$

If the study does not find the average value and the effect of the measure, it can be calculated using the T-test value (Levitt et al., 2018). To convert the value of T-test into effect size, the following equation is used.

$$d = \frac{1}{\sqrt{n}} \quad (3)$$

The value of d is the effect of the size of the data obtained, and SDWhithin is the standard deviation. To interpret the value of the effect size, the range of effect size assessments used is d = 0.2 (Small), d = 0.5 (Medium), d = 0.8 (Large), d = 1.20 (Very large), and d = 2.0 (Very large) (Griffin, 2021).

Result and Discussion

The results of the study collected for meta-analysis were 20 articles. All articles obtained are selected based on criteria in the form of a range of study years from 2012 to 2022. Studies are at the level of elementary school (ES), junior high school (JHS), high school (SHS), and university (U). All quantitative data information presented in the study was used to calculate the size effect. The characteristics and size effects of each study are shown in Table 1.

Table 1. Characteristics of Meta-Analysis Studies

Author	Year	N	Level	Country	d
(S. Jeong & Kim, 2015)	2015	74	JHS	South Korea	0.24
(K.-W. Jeong & Lim, 2021)	2021	90	ES	South Korea	-0.93
(N. H. Kang, 2019)	2019	31	JHS	South Korea	0.46
(S.-A. Min, Jeon, & Song, 2021)	2021	61	University	South Korea	-0.06
(Degeng et al., 2021)	2021	46	ES	Indonesia	1.3
(Bae et al., 2014)	2014	53	ES	South Korea	0.98
(Bae, Yun, & Kim, 2013)	2013	139	ES	South Korea	0.58
(S.-Y. Lee & Lee, 2013)	2013	83	ES	South Korea	2.15
(D.-H. Kim, Ko, Han, & Hong, 2014)	2014	141	ES	South Korea	1.12
(Cho & Kim, 2017)	2017	74	JHS	South Korea	0.78
(Huang, 2020)	2020	198	University	South Korea	1.3
(S. Y. Kim & Jeon, 2019)	2019	198	University	South Korea	0.7
(Ozkan & Umdu Topsakal, 2021)	2021	74	JHS	Turki	0.48
(Anindya & Wusqo, 2020)	2020	78	SHS	Indonesia	0.82
(Wandari, Wijaya, & Agustin, 2018)	2018	54	JHS	Indonesia	0.84
(Oh, Lee, Kim, & Kim, 2012)	2013	50	ES	South Korea	1.1
(M. G. Kim & Choi, 2013)	2013	55	ES	South Korea	0.93
(Lim & Kim, 2014)	2018	60	ES	South Korea	1.91
(Chen & Huang, 2020)	2019	99	ES	Taiwan	0.9
(Keum, 2012)	2012	42	ES	South Korea	0.89
Average Effect Size					0.71

At the beginning of the STEAM study year, it was found that there was still little STEAM implementation in learning. STEAM utilization was most found in 2020. The use of STEAM research in improving student achievement every year has increased. STEAM, as an integration of five fields of science, provides effective use in learning (S. Y. Kim & Jeon, 2019). The lowest effect size value of -0.93 is in a low category, and the highest effect size value of 2.15 is in a large category. The average value of the effect size of the studied was 0.71 in the moderate category. The results of this study are in line with previous studies that analyzed STEAM-related. STEAM mapping of student abilities is 0.76 in the medium category (S. Lee et al., 2017).

However, in contrast to the results of the STEAM analysis of creative skills on six articles that have a score of 0.82 which is in the high category (Suganda et al., 2021). The difference in the value of calculating the value of the size effect is influenced by the factor of the number of articles and the focus of the research discussed (Garzón & Acevedo, 2019).

RQ1: How does STEAM Affect Student Learning Achievement?

The results of the size effect data were used to test the hypothesis of meta-analysis research. The null hypothesis presented is the absence of the influence of STEAM on student learning achievement. The presented data were obtained from heterogeneity tests. In the heterogeneity test, data were obtained in the form of values of Q, p, and I. The values Q and I are values of heterogeneity. However, the value of I indicates the true heterogeneity of the data distribution. The null hypothesis will be accepted when the p<0.05 value. The data on the results of the heterogeneity calculation are shown in Table 2.

Table 2. Results of Meta-analysis of the Effect of Learning Achievement

Variabel	Overall	95% Confidence	
		Lower	Upper
Number of Samples (K)	20		
Heterogenity test (Q)	122.692		
Probability value (p)	<0.001		
Standar score (z)	3.16	0.270	1.150
Estimate (r)	0.710		
Heterogenity test (τ^2)	0.545	0.145	0.687
Heterogenity test (τ)	0.738	0.381	0.829
Heterogenity test (I^2 %)	85.515	61.092	88.154
Heterogenity test (H^2)	6.903	2.570	8.442

The results of the analysis showed that the effect size of the 20 analyzed studies was heterogeneous, with a value of Q= 122,692; p<0.001, for a degree of confidence of 95%. Thus, a random effect model is suitable for use to estimate the average effect size of the analyzed study. The results of the random effect analysis showed a positive correlation between the influence of STEAM use with learning achievement, with a value of 0.71 in the moderate category. In addition, a z score with a score of 3.16 provides information that there is an increase in the significance of using STEAM on student science learning achievement. The use of STEAM can increase interest and emotions in learning at school (Yuan et al., 2022). The ability of students to learn through STEAM has increased in understanding of the material presented (Cho & Kim, 2017). The results of heterogeneity indicate the influence of moderator variables on STEAM in improving learning achievement. The results of heterogeneity indicate the influence of moderator variables on STEAM in improving learning achievement. In addition, based on the estimated point and interval of confidence shown in Figure 2. The 95% confidence level is at the lowest and highest values of 0.27 and 1.15. While the average effect size value is 0.71 in the medium category. The integration of several fields, such as science and technology science in learning has a cognitive enhancing effect on students (A Asrizal et al., 2022; Nazifah & Asrizal, 2022)

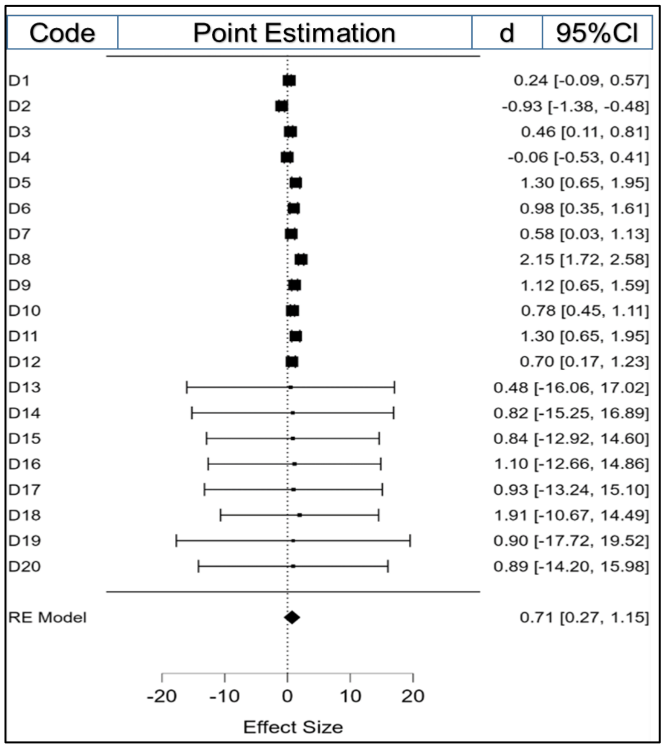

Figure 2. Forest plot

RQ2: How does STEAM Affect by Education Level?

To determine the influence of STEAM based on the level of education, the combined heterogeneity (Qw) and intermediate heterogeneity (QB) values are calculated. The magnitude of the moderator variable test value in the form of the influence of STEAM on education level is shown in Table 3.

Table 3. Education Level

Variable	ES	JHS	SHS	University
K	11	5	2	2
Q	99.060	5.101	0.020	11.109
z	2.083	3.109	2.784	0.884
d	0.869	0.494	0.82	0.601
τ^2	0.988	0.545	0.000	0.842
τ	0.994	0.738	0.000	0.917
I^2 %	87.769	85.515	0.000	90.998
H^2	8.176	6.903	1.000	11.109
95% Lower	0.051	0.183	0.211	-0.731
95% Upper	1.688	0.805	1.214	1.933
QW				115.29
QB				7.402
p-value				0.06

Note: If the p-value < 0.05 indicates a null hypothesis rejected

STEAM concentration in learning is spread at the elementary school (ES), junior high school (JHS), senior high school (SHS), and university education levels. STEAM distribution is found most in elementary schools (ES). STEAM utilization helps elementary school students learn arts and sciences simultaneously. The smallest size effect at the school level was 0.494 in the small category. The biggest effect occurred in elementary schools, with a score of 0.86 in the large category. This result is similar to previous studies that showed the value of the size effect at the education level with a value of 0.78 in the moderate (Cho & Kim, 2017). However, the results of other studies showed different effects that had a value of -0.06 with a low category (S.-A. Min et al., 2021). The p-value obtained is 0.06 and greater than 0.05. These results provide information that STEAM has a different influence on each level of education. The use of STEAM in learning provides an increase in students' perception of the material discussed. STEAM learning has a better influence on primary school education levels (J. Kang & Jin, 2019).

RQ3: Which Country has Found the Most Studies Discussing STEAM in Science Learning on Student Learning Achievement?

The findings of the meta-analysis show that countries that apply STEAM studies in education are delivered by Indonesia and South Korea. The use of STEAM in learning has a positive effect on students in learning. The popularity of STEAM is centered in South Korea. It was found that there were 15 studies of STEAM utilization in the country. Other countries that implement STEAM Indonesia with the findings of 3 studies. Taiwan and Turkey 1 study that discusses STEAM according to specified criteria. STEAM has been widely used as an effective approach to learning in South Korea. South Korea is a country that is popular for art, and this is a factor why STEAM is widely displayed in South Korea. STEAM learning is widely applied in South Korea (J. Kang & Jin, 2019).

Bias Publication

Publication bias relates to effects that are not statistically signified (Garzón & Acevedo, 2019). Publication bias in the meta-analysis can be caused by various aspects (Furuya-Kanamori et al., 2018). The methods used in the publication are biased through funnel plots, Drawer Analysis files, and egger's regression as shown in Table 4. The results of the bias test through the funnel plot are shown in Figure 3. Bias can occur mostly located at the bottom of the funnel with asymmetrical results (Garzón & Acevedo, 2019). The results of the funnel flot show a distribution of size effects that are difficult to identify symmetry, Then interpretation based on the value of p<0.05. The value p=0.841 exceeds the required value limit, so that value identifies a symmetrical distribution of size effects. The integration of technology into learning provides motivation for students in learning (Kuen-Yi Lin, 2017). The use of STEAM in learning is effectively used in learning (N. H. Kang, 2019). STEAM gives students the to think creatively in solving problems (Jeong et al., 2021).

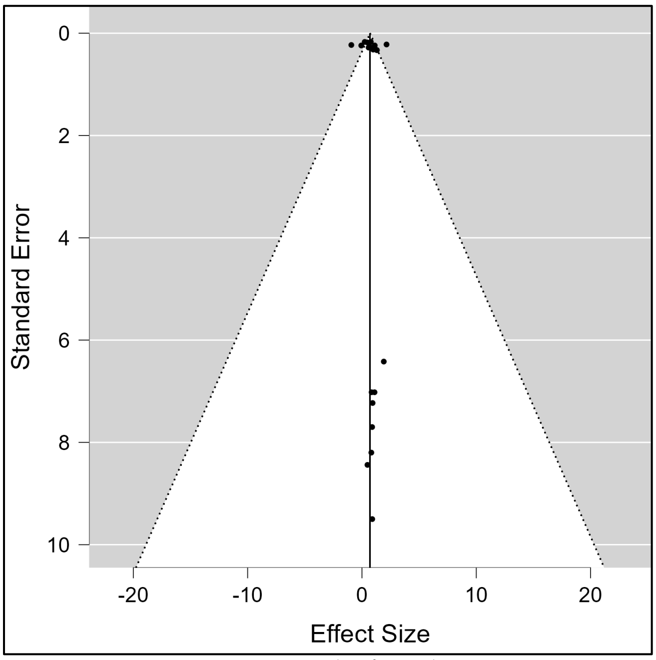

Figure 3. Plot funnel

Table 4. Publish Bias Test

Variabel	Egger's test	File Drawer Analysis	Funnel plot asymmetry
z	0.201		
p	0.841		0.558
Fail-Safe N		443.000	
Observed Significance		< .001	
Target Significance		0.050	
Kendall's τ			-0.096

Furthermore, the result of the fail-safe number, which is a procedure for evaluating the existence of a 5K+ 10 publication bias with a k value, is the number of studies included in the meta-analysis (Levitt et al., 2018). The fail-safe value N found was 443,000 at a 95% confidence level through the Rosenthal procedure. This value is greater than 5K + 10, which indicates that there is no publication bias. Based on the results obtained show that there is no bias in all tests carried out.

Conclusion

This study aims to integrate findings from several studies to idealize the effect of STEAM on student learning achievement. Based on the results of a meta-analysis of 20 research articles obtained, general information that STEAM has a moderate influence on student learning achievement with a score of 0.71. The distribution of STEAM studies is widely found in South Korea. The influence of STEAM reviewed by the level of education has a different influence on each level. The biggest STEAM effect is on the level of primary school education.

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